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CÓCOA, EMPLOYMENT AND CAPITAL IN THE GHANAIAN ECONOMY: A THEORETICAL AND EMPIRICAL ANALYSIS

Richard A. Brecher and Ian C. Parker*

1. Introduction

The present paper explores the cocoa industry's influence on employment of labor and utilization of capital throughout the Ghanaian economy. The discussion focuses upon the relationships among the size of the country's cocoa industry, the distribution of the economy's labor force between the commercial sectors and the subsistence sector, and the value of the national stock of capital in its relation to national income. These relationships are analyzed theoretically, and some of the important parameters highlighted in this way are estimated empirically for the cocoa sector. A major purpose of this analysis is to reconsider the extent of Ghana's gain or loss--in terms of degree of commercialization and magnitude of national income--arising from an increased level of foreign demand for cocoa. Departing from most of the conventional theory on economic development, the present dis-

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cussion explicitly deals (both theoretically and empirically) with the following important aspect of investment in sector-specific capital, such as cocoa trees: although such investment may be labor-using, it can also involve a long gestation period requiring intensive use of the economy's limited quantity of investible funds, and hence for many years may have repercussions on the national level and structure of capital and employment.

Section 2 develops a simple general-equilibrium model, in which heterogeneous capital goods of a sector-specific nature are produced by labor over time, as in Hicks (1973). The wage paid by the two capital-using industries (cocoa and manufacturing) is at an exogenously fixed level, as in Bhagwati (1968) and Brecher (1974 a and b); this level is determined by the productivity of the subsistence (food) sector, as in Lewis (1954) and in Fei and Ranis (1964). This model is used to show (among other things) that, in comparing different stationary states, an increased level of foreign demand for home cocoa may be associated with 1) a lower level of employment for the two commercial sectors (cocoa and manufacturing) taken as a unit and 2) lower values of national capital and income. The likelihood of these outcomes increases with the cocoa sector's relative intensity in the use of limited investible funds.

The investment costs per unit of labor and per unit of capital in cocoa production, as discussed in Section 2, are estimated empirically within the context of some simple numerical examples in Section 3. These examples are based upon the data given in the Appendix, which generates new estimates of the time structure of yields and labor inputs in cocoa by collating evidence from various sources. The numerical examples are then used to examine the dynamic properties of the model of Section 2 when the economy is not in stationary state.

Finally, Section 4 concludes the paper with some suggestions for future research.

2. The Basic Model

Section 2.1 considers the production aspects of the model. Savings and consumption are introduced in Section 2.2. Section 2.3 then compares the properties of different stationary states.

2.1. Production

Consider a simple economy that produces three consumer goods--manufactures, cocoa and food. The only two primary inputs are homogeneous labor, which is in scarce supply and used in all three sectors, and homogeneous[1] agricultural land, which is in surplus[2] and free.[3] In the course of using primary inputs over time to produce consumer goods, capital is also created, as discussed below. Every production technique exhibits constant returns to scale in all of its primary inputs.

The production relation in the food sector is

$$X_f^t = \gamma_f L_f^t \tag{1}$$

where X_f^t is the amount of food output in time t, time t being a unit interval of calendar time; L_f^t is the amount of labor used in food production in time t; and γ_f is the constant average product of labor for the best technique in the food sector. This production relation is of the point-input-point-output variety, with inputs and outputs occurring simultaneously. This simple time pattern of inputs and outputs is chosen to emphasize that production of food, in comparison with cocoa and manufactures, involves a relatively insignificant interval between initial investment of net inputs and the subsequent receipt of net outputs.

The production relations for cocoa and manufactures are of the more complicated flow-input-flow-output type, requiring both labor and time for every technique of each sector. The profile of inputs and outputs of a typical technique in sector i can be described in terms of the following equations:

$$X_i^t = \sum_{j=0}^{\Omega_i} \beta_{ij} N_{ij}^t, \qquad i = c,m \tag{2}$$

$$L_i^t = \sum_{j=0}^{\Omega_i} \alpha_{ij} N_{ij}^t, \qquad i = c,m \tag{3}$$

where X_i^t is the output of this typical technique in sector i in time t; L_i^t is the labor required by this technique in time t; β_{ij} is this technique's output from a unit process at the end of its j-th period of life; α_{ij} is the labor required by this unit process at the end of its j-th period of life; N^t_{ij} is the number of these unit processes in their j-th period of life in time t; the unit process, started at the outset of its 0-th period (by contracting to have α_{i0} labor applied at the end of the period), is terminated (with neither input nor output) at the beginning of its (Ω_i+1)-th period; and, for the sake of simplicity, each period j (of process life) coincides with some time t (as a unit interval of calendar time).

The economy is endowed with an overall supply of labor in time t (L^t) which sets the total employment level in time t:

$$L^t = L^t_f + L^t_c + L^t_m \qquad (4)$$

when the economy is using only the three techniques described in equations (1), (2) and (3).[5] Labor and investible funds (discussed below) are perfectly mobile domestically but completely immobile internationally. Profits are maximized under perfect competition. It is assumed throughout this paper that production remains incompletely specialized, with all three sectors producing positive amounts. The economy cannot affect the world price of its two importables--food, whose price is fixed at the specific level π_f, and manufactures, whose price is fixed at the specific level π_m --but does have monopoly power in determining the world price of its cocoa exports.[6] The absence of taxes and subsidies is assumed for the sake of simplicity of exposition, so that world and domestic prices are equal.[7]

The money wage in the food sector is $\gamma_f\pi_f \equiv \omega$, a constant which sets the wage that the rest of the economy must pay. Thus, the real wage in terms of manufactures is $\omega/\pi_m \equiv \omega_m$, which is also constant. This ω_m uniquely determines the rate of profit (or interest) at the specific level ρ in the manufacturing sector, according to this sector's well-known wage-interest frontier represented by the negatively sloped curve in the first quadrant of Figure 1.[8] Since competition and mobility imply that the rate of profit must be at the same level (ρ) in the cocoa sector, the real wage in terms of cocoa is uniquely determined at the specific level ω_c, according to the sector's wage-interest frontier shown in the second quadrant of Figure 1. The equilibrium price of cocoa is then $\omega/\omega_c \equiv \pi_c$, which is constant. Furthermore, ρ determines the i-th sector's choice of technology, assumed to be a single[9] technique, say the one described for sector i in equations (2) and (3).

Along lines similar to those suggested by Hicks (1973), it is now possible to define the value of the capital stock in the i-th sector in time t (K_i^t) as

$$K_i^t = \sum_{k=0}^{\Omega_i+1} \sum_{j=0}^{k-1} (\omega\alpha_{ij} - \pi_i\beta_{ij})(1+\rho)^{k-j-1} N_{ij}^t \ , \ i=c,m \qquad (5)$$

In other words, K_i^t is the value of past net inputs into the i-th sector, accumulated forward to the beginning of time t using a rate of profit (or interest) equal to ρ, for all processes living (or just terminating) in time t. In equation (5), the inner summation is the total capitalized value of all processes that are k periods old at the beginning of time t, and the outer summation totals these values for processes of all ages. The value of the total capital stock in time t (K^t) may be defined as

$$K^t = K_c^t + K_m^t \qquad (6)$$

The reason for treating capital in this way--rather than treating it as a homogeneous, perfectly malleable, primary factor of production-- is to emphasize that "transforming" cocoa capital (embodied in trees) into manufactures capital (embodied in machines) requires an intersectoral reallocation of investible funds over a number of time periods, and

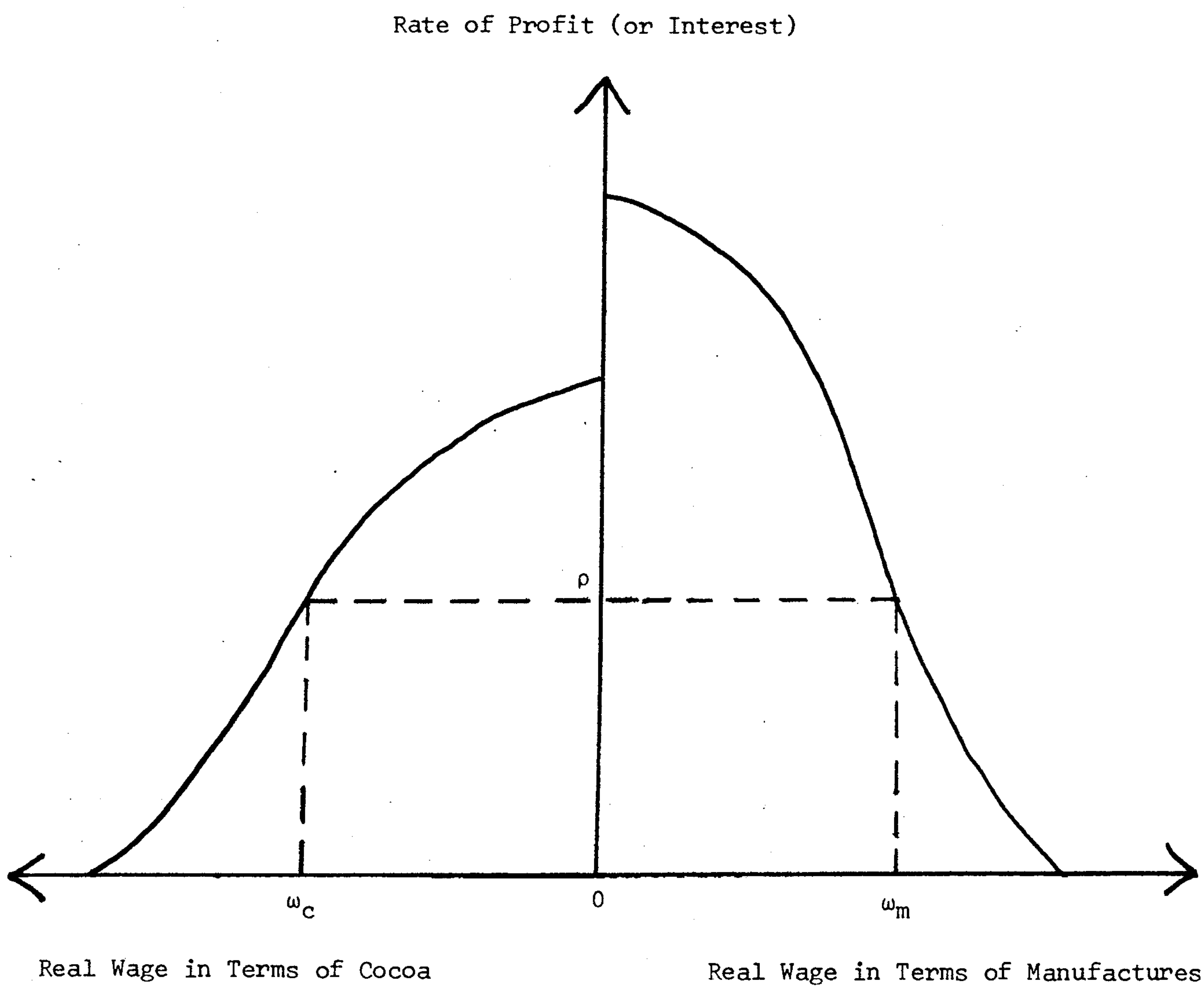
Rate of Profit (or Interest)
ρ
ω_c
0
ω_m
Real Wage in Terms of Cocoa
Real Wage in Terms of Manufactures

Figure 1

that this process may result in a change in the value of the total stock of capital.

The reasoning of Hicks (1973) indicates that K^t has the property that

$$Y^t = \omega L^t + \rho K^t \tag{7}$$

where Y^t is the net national income in time t, implying that ρK^t is a measure of net profits in time t.

Assuming no premature termination of any previously started process, gross investment in sector i in time t (I_i^t) is given by

$$I_i^t = \sum_{j=0}^{\Omega_i} \eta_{ij}(\omega\alpha_{ij} - \pi_i\beta_{ij})N_{ij}^t, \qquad i = c,m \tag{8}$$

where $$\eta_{ij} = \begin{cases} 1, \text{ if } \omega\alpha_{ij} - \pi_i\beta_{ij} > 0; \\ 0, \text{ otherwise.} \end{cases}$$

In other words, I_i^t is the total of net current inputs into all of the i-th sector's processes whose net inputs are positive in time t. Total gross investment in time t(I^t) is given by

$$I^t = I_c^t + I_m^t \tag{9}$$

2.2 Savings and Demand

The level of I^t is constrained by total gross savings in time t (S^t), so that

$$I^t = S^t. \tag{10}$$

Also, throughout this section, it is assumed that

$$S^t = \sigma Y^t \tag{11}$$

where σ, a constant, is the average propensity to save out of national income. (Alternative assumptions concerning saving could be analyzed similarly, and their implications are discussed briefly below). Although investible funds are limited to S^t, they are assumed to be perfectly mobile between sectors, as stated above.

It is assumed that domestic demand for cocoa is zero.[10] All cocoa production is offered for export, in exchange for imports of manufactures and food to supplement domestic output of these two goods. Thus X_c^t also denotes home exports of cocoa. Foreign demand for home cocoa is a strictly monotonic decreasing function of the price of cocoa (given π_m and π_f). With the cocoa price equal to π_c, foreign demand is at some specific level denoted by $\bar{Z}$. Balance-of-payments equilibrium then requires

$$X_c^t = \bar{Z}. \tag{12}$$

2.3 Comparison of Stationary States

This section compares stationary states, in order to illustrate as sharply and clearly as possible the important role of relative investible-fund intensities, which would have analogous consequences in a more general steady-state analysis (as suggested below in Section 3). Assuming that the economy is in stationary state:

$$N_{ij}^{t} = N_{i0}\ , \qquad i = c,m;\ j=0,\ldots,\ \Omega_i \tag{13}$$

for all t;

$$L^{t} = \bar{L} \tag{14}$$

for all t, assuming that all stationary states compared have the same fixed labor force ($\bar{L}$); and superscript t can be dropped from all variables.

From equations (6), (7), (9), (10), (11) and (14), it follows after simple manipulation that

$$X_m = \theta_m \sigma\omega\bar{L}/(\delta_m - \sigma\rho) - [\theta_m(\delta_c - \sigma\rho)/\theta_c(\delta_m - \sigma\rho)]X_c \tag{15}$$

$$K = \sigma\omega\bar{L}/(\delta_m - \sigma\rho) - [(\delta_c - \delta_m)/(\delta_m - \sigma\rho)\theta_c]X_c \tag{16}$$

$$\bar{L} \equiv L_c + L_m = \sigma\omega\bar{L}/\lambda_m + \sigma\rho K/\lambda_m - [(\lambda_c - \lambda_m)/\gamma_c\lambda_m]X_c \tag{17}$$

where $\theta_i \equiv X_i/K_i$, $\delta_i \equiv I_i/K_i$, $\lambda_i \equiv I_i/L_i$ and $\gamma_i \equiv X_i/L_i$, which are all constants according to straightforward use of equations (2), (3), (5), (8) and (13). Equation (15) describes the stationary-state frontier of production possibilities for cocoa and manufactures, while equations (16) and (17) describe how K and $\tilde{L}$ are related to X_c along this frontier.[11] These three equations and equation (12) together determine all equilibrium variables under present discussion. It is now possible to consider (at constant prices) the significance of an exogenously increased level of foreign demand for cocoa, by using equations (12), (15), (16) and (17) to examine the following derivatives:

$$dX_m/d\bar{Z} = dX_m/dX_c = -\theta_m(\delta_c - \sigma\rho)/\theta_c(\delta_m - \sigma\rho) \quad (18)$$

$$dK/d\bar{Z} = dK/dX_c = (\delta_m - \delta_c)/(\delta_m - \sigma\rho)\theta_c \quad (19)$$

$$d\tilde{L}/d\bar{Z} = d\tilde{L}/dX_c = (\lambda_m - \lambda_c)/\gamma_c\lambda_m + (\sigma\rho/\lambda_m)dK/d\bar{Z} \quad (20)$$

Consider the case in which

$$\delta_m - \sigma\rho > 0 \quad (21)$$

and

$$\delta_c - \sigma\rho > 0 \quad (22)$$

which yield $dX_m/d\bar{Z} < 0$. This case is interesting, because it illustrates the possibility of an increased level of foreign demand corresponding to a contracted manufacturing sector. It is also a versatile case, in the sense that it allows for the possibilities of gain and of loss, as shown below. This case is the only one discussed explicitly below, although other possible cases could be analyzed similarly.

From equations (19) and (21), it is clear that $dK/d\bar{Z} \overset{<}{\underset{>}{=}} 0$ as $\delta_m \overset{<}{\underset{>}{=}} \delta_c$. Thus, a higher level of foreign demand for home cocoa may imply a lower stationary-state value of the home capital stock--and hence of net national income according to equation (7)-- as would be the case when the investment requirement per unit of capital is higher in the cocoa sector than in manufacturing (i.e., when $\delta_c > \delta_m$).

The first expression of equation (20) indicates the change in $\tilde{L}$ for each unit of gross investment reallocated from manufacturing to cocoa production in comparing two stationary states.[12] The second expression of equation (20) indicates the change in $\tilde{L}$ caused by the total change in gross investment as the value of the capital stock varies in comparing two stationary states. From equation (19), (20), and (21) it is clear that: if $\delta_m < \delta_c$, $d\tilde{L}/d\bar{Z}$ is negative or ambiguous in sign as $\lambda_m \overset{\not>}{>} \lambda_c$; if $\delta_m = \delta_c$, $d\tilde{L}/d\bar{Z} \overset{<}{\underset{>}{=}} 0$ as $\lambda_m \overset{<}{\underset{>}{=}} \lambda_c$; and if $\delta_m > \delta_c$, $d\tilde{L}/d\bar{Z}$ is ambiguous in sign or positive as $\lambda_m \overset{<}{\not<} \lambda_c$. Thus, an increased level of foreign demand for home cocoa may imply a smaller share of the labor force employed in the commercial sectors--as would be the case, for example, when the investment requirements per unit of capital and per unit of labor are both higher in cocoa than in manufactures (i.e., when $\delta_m < \delta_c$ and $\lambda_m < \lambda_c$).[13]

3. Elementary Dynamics of the Model

Until this point, the theoretical focus has been on the comparison of different stationary states, in part to suggest the relationship of the model to others in the literature. The model, however, is equipped to consider situations of equilibrium and disequilibrium growth and decline, within sectors and for the economy as a whole. Analytical solutions are possible for the values of the major variables in such situations, under certain restrictive assumptions. In general, however, the results are quite sensitive to the behavioral and other assumptions adopted.

This section illustrates, by means of stylized examples,[14] certain phenomena characteristic of periods of growth, decline and transition. In order to highlight these phenomena, the internal dynamics of a single sector--a stylized cocoa sector--are analyzed. For ease of exposition, it is assumed that other sectors adjust appropriately in relation to changes in the cocoa sector.[15] Within the section, however, there is a brief discussion of the consequences if "appropriate adjustments" in other sectors violate aggregate feasibility constraints.

The following cases are depicted: zero growth or stationary state, which serves as a benchmark case; steady-state growth and decline; and transition from one stationary state to another, as a result of a sustained increase in the level of new plantings.

The major conclusions which the examples illustrate are as follows. Coefficients such as the δ_i and the λ_i, while constant for any given rate of steady growth, should properly be considered as functions of the rate of growth of a sector, in a general steady-state analysis. Moreover, while these coefficients are constant in a situation of steady-state growth or decline (given the growth rate), they will in general vary over time in periods of transition between steady states. This fact underlines the possibility that, in disequilibrium situations, aggregate liquidity constraints may cause unforeseen premature truncation of processes. This result can occur because of the intertemporal complementarity of inputs and outputs highlighted in the model. The basis for these conclusions is illustrated below.

The stylized time profile of inputs and outputs, shown in Table I, is based on the data in the Appendix, assuming (without loss of generality) that the unit process requires one acre. The profile has 5 periods, each of whose coefficients represents the average value of the corresponding Appendix coefficients over an 11-year period. Inputs and outputs are assumed to occur at the midpoint of each period. Capital values are measured at the beginning of each period.[16] Tables II and III are based on the coefficients of Table I, and are fairly self-explanatory. The following remarks should highlight their main significance.

Table II has two basic purposes. The first is to provide reasonably realistic estimates for the average aggregate variables X_c^t/N_c^t, L_c^t/N_c^t, K_c^t/N_c^t and I_c^t/N_c^t in three cases of steady-state growth at empirically plausible rates $g(g \gtreqless 0)$;[17] where $N_c^t \equiv \sum_{j=0}^{\Omega_c} N_{cj}^t$, which denotes total cocoa acreage in time t (given the assumption that the unit process requires one acre.) The second purpose is to use these estimates to develop the values of the coefficients θ_c, δ_c, λ_c and γ_c, as they vary with

TABLE I

TIME PROFILE OF BASIC COEFFICIENTS OF THE UNIT PROCESS

Age Range (Years)	Period	β_{cj} (Output in Loads)			$\pi_c\beta_{cj}$	α_{cj}	$\omega\alpha_{cj}$	$\pi_c\beta_{cj}-\omega\alpha_{cj}$	K^t_{cj}/N^t_{cj}
		Cocoa	Food (Cocoa-equivalent)	Total	(Revenue in N₵)	(Input in Mandays)	(Cost in N₵)	(Net Revenue in N₵)	(Value of Capital in N₵ at ρ_c = 15.35% per year)
0-10	0	1.314	3.857	5.171	51.71	60.62	60.62	-8.91	0
11-21	1	6.138	-	6.138	61.38	26.62	26.62	34.76	19.54
22-32	2	5.232	-	5.232	52.32	17.94	17.94	34.38	17.77
33-43	3	3.177	-	3.177	31.77	10.21	10.21	21.56	10.08
44-55	4	1.122	-	1.122	11.22	3.61	3.61	7.60	3.47

Notes:
1. Capital values have been calculated assuming that the periods are actually 11 years long. For further details, see footnote 16.
2. The rate of return ρ_c = 15.35% has been calculated on the assumption that inputs and outputs occur at the midpoint of each (eleven-year) period.
3. K^t_{cj}/N^t_{cj} is the capitalized value of a unit process which is in its j-th period.
4. π_c = N₵ 10, ω = N₵ 1, and one load of cocoa = 60 lbs.

TABLE II

ILLUSTRATIVE STEADY-STATE GROWTH PATHS

Composition of Cocoa Tree Stock (with growth rate g per period)

Age (j)	4	3	2	1	0
Acreage (N^t_{cj})	N^t_{c4}	$N^t_{c4}(1+g)$	$N^t_{c4}(1+g)^2$	$N^t_{c4}(1+g)^3$	$N^t_{c4}(1+g)^4$

	Case I: Stationary State (g=0)	Case II: Steady-State Growth (g=50% per period: 3.75% per year)	Case III: Steady-Decline (g=-33% per period: -3.62% per year)
X^t_c / N^t_c	4.17	4.90	3.23
L^t_c / N^t_c	.10	.15	.06
K^t_c / N^t_c	10.17	9.55	9.17
I^t_c / N^t_c	1.78	3.42	.68
$I^t_c / \pi_c X^t_c$	4.28%	6.99%	2.09%
$\theta_c = X^t_c / K^t_c$	.41	.51	.35
$\delta_c = I^t_c / K^t_c$	.175	.36	.074
$\lambda_c = I^t_c / L^t_c$	17.82	23.54	10.95
$\gamma_c = X^t_c / L^t_c$	41.68	33.69	52.28

Notes 1. The units of variables are the same as in Table I, except that L^t_c has been converted to man-years (assuming 1 man-year= 238 man-days).

TABLE III

EXAMPLE OF TRANSITION FROM ONE STATIONARY STATE TO ANOTHER

	Time					
	T	T+1	T+2	T+3	T+4	T+5
N^t_{c0}	10	20	20	20	20	20
N^t_{c1}	10	10	20	20	20	20
N^t_{c2}	10	10	10	20	20	20
N^t_{c3}	10	10	10	10	20	20
N^t_{c4}	10	10	10	10	10	20
N^t_c	50	60	70	80	90	100
X^t_c / N^t_c	4.17	4.34	4.59	4.67	4.51	4.17
L^t_c / N^t_c	.10	.126	.124	.118	.109	.10
K^t_c / N^t_c	10.17	8.47	10.06	11.02	10.92	10.17
I^t_c / N^t_c	1.78	2.97	2.54	2.25	1.98	1.78
$I^t_c / \pi_c X^t_c$	4.28%	6.8%	5.5%	4.8%	4.4%	4.28%
$\theta^t_c = X^t_c / K^t_c$	.410	.51	.46	.42	.413	.410
$\delta^t_c = I^t_c / K^t_c$	.175	.35	.25	.20	.181	.175
$\lambda^t_c = I^t_c / L^t_c$	17.82	23.57	20.48	19.07	18.17	17.82
$\gamma^t_c = X^t_c / L^t_c$	41.68	34.44	37.02	39.58	41.38	41.68

Note: 1. The units of variables are the same as in Table II.

2. The Greek-letter coefficients now require superscript t, since they are no longer constants.

the growth rate.

Table III provides the values for the same coefficients in a highly stylized transition path from one stationary state to another. The path, which results from a once-for-all increase in the level of new plantings, illustrates the point that outside steady states the values of the coefficients will generally be changing from period to period. If the sector eventually converges to steady state at the original rate of growth, then as shown in the present example, the end points of the transition will (as expected) have the same values for the relative coefficients, although absolute levels of employment, capital and income may be different.[18]

The above considerations suggest that policy conclusions which apparently follow from analyses based on comparison of stationary states must also be assessed in terms of the costs and benefits that occur during the period of transition from one stationary state to the other.

4. Conclusion

The numerous simplifying assumptions made throughout this paper suggest many avenues for further research. A few of the possible extensions, additional to those already discussed in the foregoing sections and in the Appendix, are considered briefly here. Broadly speaking, these possibilities relate to the treatment of three aspects--productive inputs, technology, and sectoral differences.

To deal with recurrent labor shortages, due to factors such as seasonal peak demands in agriculture and imperfections in labor mobility, a flexible-wage analysis would be appropriate. Similarly, an explicit treatment of variations in land rents would be needed to cope with a diminishing abundance of agricultural land. The abusa system of sharecropping in the cocoa sector has implications for the distribution of income among wages, profits and rents, which suggest certain extensions [see Brecher (1972)]. To deal effectively with non-labor inputs, further consideration should be given to inter-industry flows and imported inputs. To the extent that there are intersectoral immobilities of investible funds-- despite the powers of taxation and subsidization vested in the Government and the Cocoa Marketing Board--these frictions should be incorporated explicitly into the discussion. It is also important to incorporate the fact that the rate of savings may be varied, even under constrained liquidity, by (for example) intensifying work on cocoa farms or reallocating family labor from non-cocoa to cocoa activities.

The desirability of considering technological change is suggested by the rapid increase in the use of Amazon cocoa (as compared with the more traditional Amelonado variety) and by the opportunity of using new and improved machinery in other sectors. Also important for consideration is the possibility of less significant changes [or "minor switches" in the terminology of Hicks (1973)], as (for example) when cocoa farmers respond to various factors (such as price or climatic changes) by adjusting their profile of inputs and outputs without contracting or expanding their stock of productive trees. In addition, to deal with intra-industry differences between small-, medium- and large-scale practices, as discussed by Battacharya and Potakey (1969) for cocoa and by Steel (1973) for manufacturing, the analysis should be extended to allow explicitly for the simultaneous use of more than one technique in a given sector.

Along the lines suggested in the present paper for the cocoa sector, more detailed consideration should be given to the empirical properties of the manufacturing sector. Furthermore, it would be worthwhile to expand the analysis to include additional sectors, such as non-traded goods like services, whose price might fluctuate in response to changes in demand and supply.

Notwithstanding the significance of these factors, the basic model as it now stands serves at least the following two purposes. For one, the model suggests important policy implications of the time structure of capital, as a determinant of employment distribution between sectors. In addition, the model suggests a method for estimating this time structure and for analyzing its effects.

FOOTNOTES

[1]Although cocoa cannot be grown in many areas suitable for food production while food can be grown in the cocoa belt, this difference can be ignored in this paper, since land is assumed to be in surplus.

[2]According to Morgan and Pugh (1969, p. 521), "Except in the crowded areas of the south-east, in parts of Sierra Leone, in Western Senegal and in Mossi and Hausa districts, there is no land shortage in West Africa. The limitation on productivity has lain in the limit to which the cultivator can extend the area under cultivation with his present techniques." Although there may be increasing pressure of population in parts of Ghana [see Killick (1966 a, p. 218)], land shortage in food agriculture does not seem to be a problem in most areas of the country. In any case, at least the historical relevance of the surplus-land assumption would probably be accepted by most experts.

According to Hill (1967, p. 282), writing about cocoa: "It is to be presumed that owing to the introduction of the capsid sprayer many hitherto marginal lands have become worth planting, so that the supply of plantable lands in the possession of farmers has suddenly increased. It is easy to understand why the migrant farmers themselves are not worried by the prospect of land scarcity in the foreseeable future; and this quite apart from the fact that the re-establishment of the devastated lands will occupy many of them for years to come...It should always be remembered that the original planting of their southern Akim lands occupied many migrant farmers for a quarter of a century or more." Quoting Hill (1970, p.25) once more: "Much land that was acquired in the 1930's has never yet been planted, although suitable for cocoa."

According to Benneh (1968, p. 61), also discussing cocoa: "In certain cases, people even clear plots of land which they do not intend to cultivate during the current farming season with the sole purpose of staking their claims over them." This practice would make cocoa land appear more fully utilized than it actually is.

Direct evidence of cocoa land still available for new planting or rehabilitation (after periods of disease or pest infestation) is the Ghana Government's current Eastern Region Cocoa Rehabilitation Project, involving 36,000 acres of new planting and 54,000 acres for rehabilitation.

Admittedly, many experts would still argue that cocoa land is scarce, or at least becoming scarce, today. If so, the surplus-land assumption still has historical relevance, since cocoa land was undoubtedly in abundance during the earlier years of cultivation.

[3]Without changing any of the main results, the analysis extends easily to the cases in which the surplus land receives a traditional rental rate that is either a fixed fraction of output, a fixed fraction of the wage rate or a fixed absolute amount.

[4]Other possible techniques in sector i could be characterized by coefficient sets such as $(\Omega_i', \alpha_{ij}', \beta_{ij}')$, $(\Omega_i'', \alpha_{ij}'', \beta_{ij}'')$ and so on. Under the assumptions made below, however, it will be shown that only one technique will ever be used in sector i.

[5]Unemployment of the Harris-Todaro (1970) variety could be incorporated easily into the model, without qualitatively affecting any of the main results reported below.

[6]As a small trader in world markets for manufactures and food, Ghana's influence on international prices of these goods is probably negligible. On the other hand, as a major supplier of cocoa [see Gill and Duffus (1973)] Ghana is undoubtedly able to influence the world price of cocoa [see Blomqvist and Haessel (1972)].

[7]The analysis could be extended easily to incorporate a difference between the world price of cocoa and the price received by the domestic producer. If this were done, the resulting tax revenues of the government would be included in net national income. In this case, the higher level of cocoa exports discussed in Section 2 below would be associated with a reduced level of net losses for the exporting country. Subsidized provision of government services can likewise be readily incorporated into the model.

[8]This frontier is the outer envelope of all of the i-th sector's wage-interest curves, each of which corresponds to one of the i-th sector's techniques, such as the one described in equations (2) and (3). Along this envelope, the rate of profit (or interest)--which is the internal rate of return (equal for all time periods)--is a monotonic strictly decreasing function of the wage rate, assuming that every process can be terminated at any time without any cost (except for the opportunity cost of not continuing the process). For a more detailed discussion, see Hicks (1973) and Nuti (1973).

[9]If several techniques in sector i were equally profitable at profit rate ρ, the analysis of this section would be qualitatively unchanged as long as all of these techniques were used in fixed proportions.

[10]This assumption, which is a realistic approximation for Ghana, is not necessary but greatly simplifies the analysis.

[11]Although X_f^t does not appear explicitly here, $X_f^t = \gamma_f(\bar{L}-\tilde{L})$, from equation (1) and from the fact that the subsistence sector absorbs any labor not employed in the commercial industries.

As should be apparent, the relationship shown in equation (15) is a perpendicular projection from the transformation hyperplane in X_f-X_c-X_m space into X_c-X_m space, given the parameter values.

[12]The role of λ_i $(i = c,m)$ in determining $\tilde{L}$ here is analogous to the role of $\bar{k}_i$ $(i = 1,2)$ in determining L in Brecher (1974b). A similar role is played here by δ_i $(i = c,m)$ in determining K. The reader is cautioned, however, that λ_i and δ_i generally cease to be constant out of steady state.

[13]By similar reasoning, the following results could be derived. First, if savings out of wage income were assumed to be zero, it would not be possible to have $dX_m/d\bar{Z} \leqq 0$, $dK/d\bar{Z} = 0$ or $d\tilde{L}/d\bar{Z} = 0$; and $dK/d\bar{Z} < 0$ and $d\tilde{L}/d\bar{Z} < 0$ would each require relaxation of the assumption that domestic demand for cocoa is zero. Second, if the average propensities to save out of wages and profits were unequal (but still

constant and positive), it would still be possible to have $dX_m/d\bar{Z} \lesseqgtr 0$, $dK/d\bar{Z} \lesseqgtr 0$ and $d\tilde{L}/d\bar{Z} \lesseqgtr 0$, as under the present saving assumption stated in equation (11).

[14]These examples are a prelude to full-scale simulation analysis, using a 55-period model based on the data generated in the Appendix. Certain characteristic phenomena, however, can be demonstrated more clearly in the five-period model, with a sufficient approximation to medium-term reality.

[15]This "appropriate adjustment" implies that, if there is a divergence between savings generated by and investment required in the cocoa sector at any time along a given path of cocoa growth (decline), this net surplus (deficit) of savings will be absorbed (provided) by the other sectors, given the assumption of incomplete specialization. On steady-state growth paths at rate g ($g \gtreqless 0$), consistent with the growth of demand at constant prices, "appropriate adjustment" by other sectors can clearly occur without violating aggregate feasibility constraints. Outside steady state, however, "appropriate adjustment" by other sectors can involve premature truncation of processes in the manufacturing sector. Premature truncation would occur, for example, in any period whose required net inflow of savings into cocoa exceeded the sum of net savings in the food sector plus the surplus of savings over required investment in the manufacturing sector.

[16]This procedure enables calculation of the capital values and of ρ_c, the rate of return in the cocoa sector, which are not unrealistic. The value of ρ_c is intermediate between estimates made by Rourke (1973) and implicit in Bateman (1973). The capital values and ρ_c were derived assuming that the periods are in fact 11 years long, in order to obtain a reasonable estimate for ρ_c and to suggest appropriate relative magnitudes for the capital values. Clearly this implies that net profits do not equal $\rho_c K_c^t$ (since this equality is strictly true only with the procedure of Section 2 or in the case of continuous time), but that fact is of secondary importance for present purposes.

[17]While steady annual growth at a rate of 3.75% per year may seem high, estimates cited in the Appendix suggest growth in acreage of from 41% to 54% between 1953 and 1964, and a decline of 15% from 1964 to 1970. (These periods, of course, did not fulfil the conditions of steady-state growth.)

[18]The behavior of the coefficient values in Tables II and III outside stationary state follows fairly smooth patterns. Most of these patterns have some intuitive appeal given the reasonably regular profiles of inputs and outputs in Table I. With more complex profiles (including the full 55-period cocoa profile), however, monotonically varying values for the coefficients as functions of the rate of steady-state growth are the exception, rather than the rule [as the value of K_c^t/N_c^t (Table II) suggests]. Similarly, coefficient values in periods of transition between steady states will frequently contain numerous peaks and troughs.

APPENDIX

A-1. Introduction

This Appendix collates evidence from a number of sources to develop estimates of the time structure of both yields and labor inputs in the Ghanaian cocoa sector. These estimates serve as a basis for the analysis in Section 3 above. Several points regarding the degree of abstraction and the proper range of application of the estimates should be made at the outset.

First, the age-specific relation between inputs and yields employed in this study is an aggregated average concept. This relation therefore omits explicit consideration of certain variations which can occur from farm to farm and from region to region, as a result of a number of factors, some of which are examined above in Section 4. For this reason, the Appendix also includes reference to data which indicate the sources and extent of these variations, and thereby provides an implicit cautionary note concerning the limitations of these aggregated estimates in more microeconomic applications.

Secondly, in agreement with the assessment of Galleti *et al.* (1956, p. 188), who argue that "In the long-run the age of farm is the most important determinant of yields," the present method ignores several factors which have been of some importance in Ghanaian cocoa development.[1] In particular, the model gives no weight to the current producer price of cocoa as a determinant of labor inputs and yields, with a given stock of cocoa trees. Rather, it is assumed that yield per acre of a given age will be constant (provided that premature truncation does not occur), because the same process is always used. By this "fixed-process" assumption, the model also excludes the possibility that increased or reduced labor inputs in one period can affect the current or subsequent yields of a given stock of trees, since by assumption no such input variation (for price or other reasons) occurs. More generally, the model does not explicitly consider such factors as annual rainfall variation, the extent of diseases such as Swollen Shoot and Black Pod and of pests such as capsids, or the role of Gammalin spraying and other policy measures, although work by Bateman (1973) suggests that these factors do affect the supply of cocoa in any given year.[2]

It is not possible to estimate directly the yield per acre of cocoa of each age, averaged over all Ghanaian cocoa farms, since output and acreage data for every age are not available.[3] There is, however, some output and acreage information on a more aggregated basis, as well as information on yield structure from research experiments. These three sets of data can be used, under certain assumptions, to generate indirect estimates of yield per acre of cocoa of each age, as shown in Section A-2. Section A-3 uses these estimates, together with microeconomic field-survey data on labor inputs in farm establishment and harvesting, in order to estimate a time profile of per-acre labor inputs corresponding to the estimated time profile of yields.

A-2. Estimating Age-Specific Yields Per Acre

Without loss of generality, let the unit process in cocoa correspond to one acre. Thus, N^t_{cj} denotes the number of acres devoted to j-year-old cocoa in time t, and β_{cj} denotes the yield per acre of j-year-old cocoa. Also, let $\mu_{cj} \equiv \beta_{cj}/\beta^*_c$, where β^*_c denotes the maximum value of β_{cj} (occurring at the most productive age), and μ_{cj} is called the relative yield of j-year-old cocoa.

A-2.1. Evidence on Relative Yields

One set of data used here concerns research-station estimates of μ_{cj} and Ω_c, denoted respectively by $\hat{\mu}_{cj}$ and $\hat{\Omega}_c$, which are obtained from experimental trials conducted at Tafo by the Cocoa Research Institute, as reported by Bateman (1973) and reproduced below in Table A-I. It is assumed that

$$\Omega_c = \hat{\Omega}_c \tag{A-1}$$

and that

$$\beta_{cj}/\beta^*_c \equiv \mu_{cj} = \hat{\mu}_{cj} \tag{A-2}$$

which is not inconsistent with the generally acknowledged difference in per-acre (absolute) yields between actual and experimental fields. Equation (A-2) implies only that the ratio between actual and experimental yields per acre is the same for every age.

It should be noted that there are various factors which may cause even the relative-yield profiles to differ between research stations and actual farms. For example, it appears that lower planting densities in research trials may reduce early yields per acre and increase later yields per acre, particularly if replanting to maintain tree density and canopy is undertaken for trees which die out at an early age.[4] Similarly, it is possible that additional inputs of labor in earlier years could increase experimental output in subsequent years.[5] Both factors, insofar as they were operative, would tend to impart an upward bias to the experimental relative yields for later years, as compared to relative yields achieved on actual cocoa farms. Given the limited amount of actual field data on age-specific yield profiles in Ghana, however, it is assumed that the overall effect of these and similar factors is statistically negligible.

Evidence from other sources tends to reveal a roughly similar age profile of relative yields. Field interviews in Mampong-Ashanti, conducted by Boaten (1973, p. 10) with personnel of the Ministry of Agriculture, generated the estimates reproduced below in Table A-II. In the Boaten data, as in Table A-I, the peak of relative yields occurs on farms 20 years old. Boaten's relative yields for early and late years, however, are higher than the corresponding coefficients in Table A-I. Boaten does not indicate whether the estimates given in the interviews are systematic ones based on statistical sampling, or instead are "rule of thumb" estimates based on casual empiricism (by agricultural officers) on "best-practice" farms. In the latter case, an upward bias very well may be present in the estimates for early and later years.

Elliott (1973) has reported yield data from a cross-section survey of fields planted in the Ivory Coast at much lower density than is normal on Ghanaian cocoa farms. Table A-III reproduces these data, and adjusts them to give a constant average density of trees. The Elliott statistics as adjusted do not allow for tree attrition, and hence may be expected to overstate yields per acre on older farms, in the absence of additional labor inputs on fields approximately 15 years of age and over. These adjusted statistics suggest that, at least in the Ivory Coast, peak yields were achieved somewhat earlier and decline in yields was somewhat more rapid than in the Tafo trials. Given the inter-country differences in field densities and in other conditions, the discrepancies between the Elliott and the Tafo data do not seem significant enough to warrant an adjustment of Table A-I for equation (A-2).

Yield patterns on cocoa plantations in the Dominican Republic, as reported by Mathis (1969, p. 27) and reproduced in Table A-IV, suggest a more gradual rise to maximum yield and a substantially longer productive age than do any of the Tables discussed above. It is not possible to ascertain from the Mathis data, however, whether this difference reflects primarily the effects of soil and climatic conditions, organizational considerations, land availability and labor inputs, cocoa varieties adopted, or other factors. In the absence of such information, the primary value of the Mathis data is to suggest that, under certain conditions, the longevity of cocoa fields may be substantially greater than that taken as typical of Ghanaian cocoa fields in the present study.

The resurvey of Akokoaso in Eastern Ghana, undertaken in 1970-71 by Okali and Kotey (1971) to trace developments since Beckett's (1947) original survey of the village in 1935, suggests that the longevity of fields corresponds to that shown in Table A-I, although there is a significant variation in the longevity of cocoa fields prior to their abandonment in Akokoaso.

The Akokoaso resurvey by Okali and Kotey (1971, pp. 44, 46) also suggests, as does Boaten (1973), that once yields begin to decline on a given farm, little time, energy or money is allocated to that farm for purposes other than to obtain the available crop. Such patterns of farm maintenance can be expected to accelerate the rate of yield decline (and shorten the productive lifetime) of cocoa stands, relative to the rate implicit in Table A-I. This accelerated deteriation on some farms may be offset, however, by slower decline on others, as suggested by Okali and Kotey's evidence on the existence of stands more than 55 years old. Although there has been no thorough study of the precise relationship between the rate of decline and labor inputs on older farms under actual farming conditions, some allowance for the relationship has been made in the present calculation of labor coefficients.

All of the above data refer to yields on fields of a given age, rather than trees of a given age. Killick (1966b, p. 242) cites the apparently anomalous finding that individual trees do not reach full bearing until they are over 30 years of age. This finding is not necessarily inconsistent with the relative-yield profile of Table A-I, since there are changes in the tree population of a given field over time (see Jolly, 1955), and these changes will tend to shorten the period until peak yield on the field is reached and to increase the field's rate of yield decline.

A-2.2. Evidence on Age Structure of Ghanaian Cocoa

The second set of data used here concerns acreage totals for (mutually exclusive and exhaustive) age groups. For the k-th age group ($k = 0,\ldots,h$), total acreage may be denoted by $\sum_{j \in J_k} N^t_{cj}$, where J_k is the set of all j within the k-th age group, and h+1 is the number of such groups. Estimates of $\sum_{j\varepsilon J_k} N^t_{cj}$ for t = 1958-1960 and h = 3, provided by the Ministry of Agriculture as reported by Killick (1966b, p. 243), are reproduced below in Table A-V. These data are extrapolated (from 1959) to provide estimates of $\sum_{j\varepsilon J_k} N^t_{cj}$ for t = 1970 and h = 4, which appear in Table A-VI. This extrapolation relies upon the assumption that total acreage of each 1959 age group is equally divided between all ages within the group. This "equal-distribution" assumption may be stated generally for acreages within the k-th age-group, as follows:

$$N^t_{cj} = \bar{N}^t_{ck} \equiv (\sum_{j\varepsilon J_k} N^t_{cj})/n_{ck}, \qquad k = 0,\ldots h;\ j\varepsilon J_k, \qquad \text{(A-3)}$$

where $\bar{N}^t_{ck}$ is the average acreage for each age within the k-th age group in time t, and n_{ck} is the number of ages within the k-th age group.

A few comments on this assumption are in order. If Moss's (1953) age-group estimates (Table A-V) are extrapolated to 1958-60, assuming that acreages within each 1953 age group were equally distributed between ages, the results are anomalous when compared with the actual age-group estimates for 1958-60. This equal-distribution projection from 1953 data produces an abnormally low estimate for the proportion of acreage in the 16- to 30-year age group in 1958-60, relative to what was actually observed, and an exceptionally high projection for acreage over 30 years of age. There are likely two major explanations for these discrepancies.

First, the Moss (1953) age-group estimates are based on only 1.7 million of the 2.75 million cocoa acres surveyed to July 1953, and relate to the older cocoa districts. Moss (1953, p. 89) considered that "in view of this and the very extensive recent plantings not yet surveyed, it is to be expected that for the country as a whole the proportion of young trees is a good deal higher" than for the 1.7 million acres. If a large proportion of the million remaining surveyed acres was in the 8- to 15-year year age group in 1953, then the 1958-60 projection for the 16- to 30-year group would correspond more closely to the actual 1958-60 estimates.

The second factor which would reduce the discrepancy relates to the realism of the equal-distribution assumption. Since the 1953 age-group estimates are based on the older districts, it is probable that a higher proportion of trees in the acreage analyzed was in the over-30-year age group, and that a higher relative proportion was of an age such that they would be moribund by 1958-60. Excessive emphasis should not be placed on this second factor, in view of the expansion of plantings and of output during 1900-1923; but given the relative-yield assumption in equation (A-2), farms at peak bearing age around 1920 would on average be nearing the end of their productive lives by 1953.

A-2.3 Combining the Evidence

From equations (2), (A-1), (A-2) and (A-3), it follows after simple manipulation that

$$\beta_{cj} = X_c^t \hat{\mu}_{cj} / \sum_{k=0}^{h} (\bar{N}_{ck}^t \sum_{j \varepsilon J_k} \hat{\mu}_{cj}) \qquad j = 0,\ldots, \hat{\Omega}_c \qquad \text{(A-4)}$$

Using equation (A-4), all β_{cj} can be estimated with available data on X_c^t

for 1970 from Gill and Duffus (1973), on $\hat{\mu}_{cj}$ and $\hat{\Omega}_c$ from Table A-I, and on $\bar{N}^t_{ck}$ (t = 1970 and k = 0,...4) calculated from Table A-VI. The resulting estimates of β_{cj} are given below in Table A-VII.[6]

The average maximum yield per acre on this calculation is 392.4 lbs/acre (on fields 15-20 years old). Although this estimate may appear somewhat low, it must be remembered that the figure refers to both "pure" and "mixed" cocoa stands. Furthermore, when the relative yields of Table A-VII are applied to the 1958-60 acreage estimates in Table A-V, using the equal-distribution assumption, a production estimate of 349,800 long tons is generated. This figure is only 7.97% higher than 324,000 long tons, which is the five-year average centered on 1959/60 using the annual production data of Gill and Duffus (1973). The size of this discrepancy provides some indication of the reliability of the relative-yield estimates in Table A-VII. These estimates could be improved by more accurate knowledge of 1953 and 1958-60 total acreage, informed relaxation of the equal-distribution assumption, knowledge of changes in the ratio of pure to mixed cocoa stands, inclusion of short-run factors such as rainfall, and use of similar data. For present purposes, however, the estimates of relative yield appear sufficiently accurate.

Parenthetically, when the 1970 acreage estimates in Table A-VI are compared with the corresponding stationary-state estimates (for an equivalent area) given in Table A-VI, an unpromising prognosis is suggested for total Ghanaian cocoa production through most of the 1970's. This is particularly true for the latter half of the decade, even in the event of an intensification of the rate of plantings during the early 1970's.

A-3. Estimating Age-Specific Labor Inputs Per Acre

The most thorough recent sources of microeconomic data on labor inputs in cocoa, based on actual observations on Ghanaian farms, are Okali (1973) and Rourke (1973). Their findings have been used extensively in developing the labor input coefficients reported in this section of the Appendix.

Two points should be noted concerning the input coefficients of Okali (1973) and Rourke (1973). First, they are based on data drawn from intensive study of farming practices in restricted sites in the Brong-Ahafo and Eastern Regions, respectively. The assumption that these data accurately represent standard farming practice throughout the Ghanaian cocoa belt is justified only by the scarcity of similarly detailed data from other regions, and by the relatively close correspondence between the coefficients derived from study of two different regions.

Secondly, the labor input data relate only to the labor necessary to bring cocoa to purchasing stations. It is reasonable to estimate that, on average, approximately N¢ 60 per ton are required to transport one long ton from the purchasing station to the docks for export. As a result of the shortage of appropriate data for the transport and administration sectors, the time structure of labor inputs into transportation has not been calculated in the present study, just as net export tax revenues per ton have not been calculated. The intention here is to provide an indication of the net private return within the cocoa sector, although the social return to cocoa could be derived by utilizing export prices and deducting the import component of transportation and of cocoa production costs, if these statistics were known.

The basic labor coefficients for cocoa are laid out in Table A-VIII, on the basis of estimates derived from Okali's (1973) and Rourke's (1973) data, as applied to the absolute yield coefficients of Table A-VII.

Normal practice in cocoa planting involves interplanting of cocoa with plantains, cocoyams or other foodcrops. Plantains are planted as a shade crop for the immature cocoa during the gestation period and,like cocoyams,as a source of food. The labor devoted to plantains is therefore required in the cocoa production process, while the net returns from all food crops (whether consumed on the farm or marketed) relax the liquidity constraint on farmers during the period when the cocoa has not yet begun to bear. The inputs and returns for plantains and cocoyams are shown in Table A-IX. The significance of interplanting is underlined by the fact that areas with a high proportion of new cocoa acreage tend to be food-surplus areas, while old cocoa areas tend to be food-deficit areas.[7] The appropriate procedure is therefore to include food crops with cocoa in estimating input and output coefficients, as has been done in Table A-VIII.

Purchased inputs other than labor should properly be accounted for in terms of their own time structure of production. Insofar as these inputs (such as Gammalin, sprayers and farm implements) are imported manufactured products, however, it is reasonable to value them at the cost of exports for which they are exchanged or, as an approximation, at the value of labor inputs into the cocoa sector. This approximate procedure has been followed in calculating the coefficients in Table A-X.

APPENDIX FOOTNOTES

1. Despite this emphasis, Section 3 suggests that the underlying model is flexible enough to deal with a medium-run horizon, intermediate between that of short-run supply-response models and the horizon of long-run steady-state models.

2. Bateman's (1973) model is probably the most thoughtful and sophisticated existing econometric model of Ghanaian cocoa supply. Nonetheless, his model (like the present one) omits some significant variables which *a priori* appear to have had an important structural effect on the supply of cocoa in Ghana in the period since 1939.

Bateman's (1973) model includes an "effort" coefficient relating the producer price and cost of production of cocoa, a rainfall coefficient, a Gammalin coefficient, and coefficients for the incidence and control of Swollen Shoot. The model, however, necessarily relies on an indirect measure of the cocoa capital stock, and omits adequate explicit consideration of factors such as the following: the extent and rate of expansion of capsid infestation, as distinct from the magnitude of prevention and control measures; the possible declining secular effectiveness of Gammalin as a method of capsid control [see Bateman (1973) and Leston (1973)]; the pattern of extension of the transport system, which facilitated the introduction of cocoa into previously economically inacessible areas, such as parts of the western Brong-Ahafo Region and the Western Region; the implications of the Aliens' Compliance Order, and the effectiveness of its enforcement (Addo, 1972), for cocoa output and total employment; the return to farmers from food crops planted along with cocoa, which significantly affects the age profile of returns; the effects of the abusa and related systems on the behavior of the "effort" coefficient; and the factors treated in footnotes 4 and 5 below.

Insofar as the Bateman (1973) model (or the present one) omits the effects of these and other such factors, its predictive capacity is correspondingly reduced.

3. Unpublished survey data collected by the Cocoa Production Division of the Ghana Cocoa Marketing Board provide the basis both for more detailed regional estimates of the age structure of the cocoa tree stock and for improved estimates of yields per acre. This survey has not been completed, however, and the data have not yet been put in systematic and publicly accessible form.

4. In general, planting densities on actual cocoa farms appear to be somewhat higher than those on research stations. Tafo research on planting densities reported by Bonaparte (1966, 1973) suggests two possible reasons for this difference. These reasons are the apparently higher variance of yield (at least in the early years) and the significantly higher weeding costs, on low-density (as opposed to high-density) plantings.

5. To the extent that the input of labor on research stations in any period is greater than economically warranted for a given discount rate, the experimental relative yields in that period and subsequent ones may be systematically biased upwards in comparison with the relative yields of actual cocoa farms. In addition, if general farming practice does not

normally include replanting of enough trees to maintain a continuous canopy, deterioration of the farms has been found to be rapid (Galletti <u>et al</u>, 1956, pp. 22, 183ff), and relative yields on such farms from about age 25 onwards may be substantially lower than those in Table A-I. Implicitly, it is assumed that the rate of decline on some fields is low enough for later-year relative yields in Table A-I to represent a reasonable weighted average of rapidly and slowly declining yields, on farms of a given age.

6. If the cocoa sector were experiencing steady-state growth in some known rate $g(\gtreqless 0)$, it would be the case that $N^t_{cj} = N^t_{co}(1+g)^{-j}$ and $N^t_{co}\sum_{j=0}^{\hat{\Omega}_c}(1+g)^{-j} = N^t_c$, where N^t_c denotes total acreage devoted to cocoa in time t. In this case, these two equations and equations (2), (A-1) and (A-2) can be manipulated easily to obtain

$$\beta_{cj} = X^t_c\,\hat{\mu}_{ij}[\sum_{j=0}^{\hat{\Omega}_c}(1+g)^{-j}]/N^t_c\sum_{j=0}^{\hat{\Omega}_c}\hat{\mu}_{cj}(1+g)^{-j} \qquad j=0,\ldots,\hat{\Omega}_c$$

which allows each β_{cj} to be calculated from available data, without the need for Table A-VI.

This procedure was not followed because acreage percentages of age groups in Table A-V do not remain constant between 1953 and 1958-60, although they would be constant under steady-state conditions. Absence of steady-state behavior is also suggested by the observation that the sector's total yield per acre, which would be constant from year to year in (constant-technology) steady-state, in fact has varied between observations, as the following data indicate.

The 1970 Ghana Sample Census of Agriculture by the Ministry of Agriculture (1972) indicates that pure and mixed cocoa land in 1970 amounted to approximately 3,587,000 acres, while a five-year average of Gill and Duffus (1973) production figures centered on 1970 indicates an average annual production of 400,200 long tons of cocoa for the period; which implies an average yield of 250 lbs. per acre. Ministry of Agriculture estimates for March 1964 (see Killick, 1966b, p. 237) indicate that 4,224,277 acres were under cocoa, so that average annual production of 447,000 tons during 1961/62-1965/66 (using Gill and Duffus data) suggests an average yield of 237 lbs. per acre. Moss (1953) reported that approximately 2.75 million acres had been surveyed in the period up to July 1953 (although not all cocoa land, particularly young cocoa land, was included in this figure), and a five-year production average centered on 1952/53 (using Gill and Duffus data) indicates an average annual production of 230,200 long tons; which implies at most an average yield of 188 lbs. per acre.

7. George Benneh, personal communication, August 1973.

TABLE A-I

AGE-SPECIFIC RELATIVE YIELDS IN EXPERIMENTAL TRIALS AT TAFO (GHANA)

Age (Years)	Relative Yield	Age (Years)	Relative Yield
0	0		
1	0	31	.686
2	0	32	.657
3	0	33	.629
4	.0216	34	.600
5	.0814	35	.571
6	.252	36	.543
7	.3628	37	.514
8	.4466	38	.486
9	.4994	39	.457
10	.5452	40	.429
11	.6208	41	.400
12	.8226	42	.371
13	.9324	43	.343
14	.9764	44	.314
15	1.0000	45	.286
16	1.000	46	.257
17	1.000	47	.229
18	1.000	48	.200
19	1.000	49	.171
20	1.000	50	.143
21	.971	51	.114
22	.943	52	.086
23	.914	53	.057
24	.886	54	.029
25	.857	55	.000
26	.829		
27	.800		
28	.771		
29	.743		
30	.714		

Notes: 1. Source: The relative yields have been adapted from Bateman(1973, pp. 55-56). For ages 1-14, the relative yield is a simple average of the relative yields that he cites. His assumption of a linear decline from year 20 to year 55 is adopted here, in the absence of conflicting experimental and field data [Cf. Galletti et al.(1956), and Okali and Kotey (1971)].

2. Relative yield for each age is derived by dividing the experimental or assumed yield per acre of that age by the maximum yield per acre (occurring at the most productive age).

TABLE A-II

AGE-SPECIFIC YIELDS FOR MAMPONG-ASHANTI (GHANA)

Age of Farm (Years)	Yield / Acre (Loads)	(Pounds)	Relative Yield
5	5-6	300-360	.367
10	6-8	360-480	.778
20	8-10	480-600	1.000
30	8-7	480-420	.833
40	6-4	360-240	.556
50	4-2	240-120	.333
60	Below 2	Below 120	.111

Source: Boaten (1973), p. 10.

TABLE A-III

AGE-SPECIFIC YIELDS FOR IVORY COAST

Age (Years)	Trees/ Acre	Pods/ Tree	Pods/ Lb.	Lbs./ Acre	Average Trees/Acre	Adjusted Lbs./Acre	Adjusted Relative Yield
5-7	456	1.4	9.65	66	462.5	67.8	.216
8-10	436	4.8	9.50	220	462.5	233.4	.743
11-15	512	6.5	9.56	347.6	462.5	314.0	1.000
16-20	496	5.5	9.53	286	462.5	266.7	.849
21-25	430	5.8	9.28	268.4	462.5	288.7	.919
26-30	445	4.7	9.50	220	462.5	228.7	.728

Notes: 1. Source: The first five columns are from Elliott (1973, p. 23). The last three columns adjust his data to provide relative yield estimates assuming constant tree density.

TABLE A-IV

AGE-SPECIFIC YIELDS FOR DOMINICAN REPUBLIC
(TRADITIONAL PLANTATIONS)

AGE(Years)	YIELD (Lbs/Tarea)	YIELD (Lbs/Acre)	RELATIVE YIELD
0-3	0	0	0
5	15	96.5	.250
13	50	321.75	.833
20	60	386.1	1.000
30	60	386.1	1.000
80	35	225.2	.583

Notes: 1. Source: Mathis (1969, p. 27).

2. One tarea = 628.86 square meters, or .1554 acres; 1 acre=6.435 tareas.

3. Yields for intermediate years are taken as linear interpolations of the benchmark yields in the table.

TABLE A-V

AGE COMPOSITION OF STOCK OF COCOA TREES (GHANA),1953 and 1958-60

Age Group	Percentage of Acreage in Stationary State	Percent of Output in Stationary State	1953 Acreage Estimate #1	1953 Acreage Estimate#2	1958-60 Acreage
0-7 (7 years)	12.7%	2.5%	13%	10%	25%
8-15 (8 years)	14.6%	20.5%	14%	17%	10%
16-30 (15 years)	27.3%	47.0%	42%	40%	42%
Over 30 (25 years)	45.4%	30.0%	30%	33%	23%
	100.0%	100.0%	100%	100%	100%

Notes: 1. Source: The figures for 1953 and 1958-60 are from Killick (1966b, p. 243) and references cited therein.

2. The stationary-state outputs are based on the relative yields in Table A-I.

3. The 1953 acreage estimate #1 (Moss, 1953) is based on 1.7 million acres out of 2.75 million surveyed.

TABLE A-VI

AGE COMPOSITION OF STOCK OF COCOA TREES (GHANA), 1959 AND 1970 (PROJECTED FROM 1959)

	1959		1970		STATIONARY-STATE (1970 acreage)		
Age Group (Years)	Area (%)	Acreage (000 acres)	Area(%)	Acreage (000 acres)	Area(%)	Acreage (000acres)	Output(
0-7 (7 yrs.)	25%	900					
8-15 (8 yrs.)	10%	360					
16-30 (15 yrs.)	42%	1512					
31-55 (25 yrs.)	23%	828					
0-11 (11 yrs.)			10.7%	384	20.0%	717	9.90%
12-18 (7 yrs.)			25.1%	900	12.7%	456	23.57
19-26 (8 yrs.)			10.0%	360	14.5%	520	25.91
27-41 (15 yrs.)			42.1%	1512	27.3%	979	31.51
42-55 (14 yrs.)			12.0%	431	25.5%	915	9.10
TOTAL	100%	3600	100%	3587	100%	3587	100%

Notes:

1. The 1970 estimates are based on a straightforward projection of 1959 acreage estimates, assuming that 1959 acreage of each age group was equally distributed between all ages in the group. New plantings (the 0- to 11-year age group) are calculated as a residual.

2. This projection assumes that 1959 cocoa area was approximately 3.6 million acres--or midway between an estimate of 3 million acres in 1953 and 4.224 million acres in 1964 (Killick, 1966b, p. 237).

3. The stationary-state output estimates are based on the coefficients in Table A-I.

TABLE A-VII

ESTIMATES OF AVERAGE AGE-SPECIFIC YIELD AND REVENUE PER ACRE (GHANA)

Age (Years)	Yield Per Acre (Lbs./Acre)	Revenue Per Acre (N¢)	Age (Years)	Yield Per Acre (Lbs./Acre)	Revenue Per Acre (N¢)
0	0	0			
1	0	0	31	269.2	44.87
2	0	0	32	257.8	42.97
3	0	0	33	246.9	41.15
4	8.5	1.42	34	235.5	39.25
5	31.9	5.32	35	224.1	37.35
6	98.9	16.48	36	213.1	35.52
7	142.4	23.73	37	201.7	33.62
8	175.3	29.22	38	190.7	31.78
9	196.0	32.67	39	179.3	29.88
10	214.0	35.67	40	168.4	28.07
11	243.6	40.60	41	157.0	26.17
12	322.8	53.80	42	145.6	24.27
13	365.9	60.98	43	134.6	22.43
14	383.2	63.87	44	123.2	20.53
15	392.4	65.40	45	112.2	18.70
16	392.4	65.40	46	100.9	16.82
17	392.4	65.40	47	89.9	14.98
18	392.4	65.40	48	78.5	13.08
19	392.4	65.40	49	67.1	11.18
20	392.4	65.40	50	56.1	9.35
21	381.1	63.52	51	44.7	7.45
22	370.1	61.68	52	33.8	5.63
23	358.7	59.78	53	22.4	3.73
24	347.7	57.95	54	11.4	1.90
25	336.3	56.05	55	0	0
26	325.3	54.22			
27	314.0	52.33			
28	302.6	50.43			
29	291.6	48.59			
30	280.2	46.70			

Notes: 1. The estimates of revenue per acre assume continuation of a real producer price of N¢ 10 per 60-lb. headload at 1973 prices.

TABLE A-VIII

AGE-SPECIFIC LABOR-EQUIVALENT INPUTS PER ACRE ON INTERPLANTED COCOA FARMS (GHANA)

Age (Years)	Labor-Equivalent Input (Man-days/ Acre)	Age (Years)	Labor-Equivalent Input (Man-days/ Acre)
0	150.30		
1	37.70	31	14.42
2	147.60	32	13.81
3	106.60	33	13.22
4	58.50	34	12.61
5	27.62	35	12.01
6	28.21	36	11.41
7	28.36	37	10.82
8	28.30	38	10.22
9	28.00	39	9.62
10	27.66	40	9.02
11	27.53	41	8.42
12	28.52	42	7.81
13	28.67	43	7.21
14	28.32	44	6.61
15	27.81	45	6.01
16	27.11	46	5.41
17	26.42	47	4.82
18	25.72	48	4.21
19	25.03	49	3.61
20	24.33	50	3.00
21	23.40	51	2.40
22	22.49	52	1.80
23	21.57	53	1.20
24	20.66	54	.61
25	19.74	55	0
26	18.82		
27	17.91		
28	16.98		
29	15.94		
30	15.02		

Notes: 1. The cost calculations based on this Table assume a money wage rate of N₵ 1.00 per man day in the cocoa sector, at 1973 prices, as does Rourke (1973). Purchased inputs have been valued at their man-day equivalent in computing labor inputs. That is, the "labor-equivalent input" figures also include a small proportion of purchased inputs, valued as though they were equivalent to purchase of labor at the 1973 money wage rate . For details see Rourke.

Notes continued on following page.

Notes continued: TABLE A-VIII

2. Okali's (1973) figures for weeding and establishment inputs, which are somewhat higher than Rourke's (1973), have been adopted for ages 0 to 5. It is assumed that labor-equivalent maintenance inputs for later ages decline linearly from a level of 27 man-days per acre at age 5 to a level of 9.6 man-days per acre at age 30, and that (in response to declining yields) farm maintenance thereafter is reduced annually by 4% of its age-30 level until there is no maintenance at age 55.

3. Input figures for harvesting and marketing of cocoa are based on Rourke's (1973) estimates. Since he provides figures for only certain levels of yield per acre, the inputs per acre for other levels of yield are derived by proportional interpolation. The per-acre input (for harvesting and marketing) corresponding to any given yield in Table A-VI is assumed to equal the (interpolated) Rourke input for that same yield.

4. The input cost figures exclude the cost of obtaining rights to land. This cost represents a significant proportion of total establishment cost from the standpoint of an individual farmer. As long as cocoa land is not scarce, however, it essentially involves a straight-forward redistribution within the private sector.

TABLE A-IX

COSTS, YIELDS AND REVENUES PER ACRE

FROM FOOD CROPS ON COCOA FARMS (GHANA)

Age (Years)	Labor Input (Man-days)	Non-labor Input Cost (Man-day Equivalents)	Yield /Acre (Loads)		Revenue /Acre (N₵)	
			Plantains	Cocoyams	Plantains	Cocoyams
0	16.00	15.50	0	0	0	0
1	7.60	———	0	0	0	0
2	73.00	26.40	50	38	103.50	137.20
3	46.00	15.00	35	15	72.50	54.20
4	21.50	6.90	17	6	35.20	21.70

Notes: 1. Source: Rourke (1973 , p. 29). Rourke assumed a per-load price of about N₵ 2.07 for plantains and N₵ 3.71 for cocoyams. These figures have been adopted in the present study.

2. Non-labor inputs have been converted to man-day equivalents assuming a labor cost or wage of N₵ 1 per man day, as in Rourke (1973).

3. The labor-equivalent costs of this Table are included in the estimates of Table A-VIII.

TABLE A-X

AVERAGE ANNUAL COSTS AND REVENUES PER ACRE OF COCOA (GHANA)

AGE	REVENUE (N¢)			COST (N¢)	NET REVENUE (N¢)	AGE	REVENUE (N¢)	COST (N¢)	NET REVENUE (N¢)
	Non-Cocoa	Cocoa	Total				Cocoa		
0	0	0	0	150.30	-150.30	31	44.87	14.42	30.45
1	0	0	0	37.70	-37.70				
2	240.70	0	240.70	147.60	93.10	32	42.97	13.81	29.16
3	126.70	0	126.70	106.60	20.10	33	41.15	13.22	27.93
4	56.90	1.42	58.32	58.50	-.18	34	39.25	12.61	26.64
5	0	5.32	5.32	27.62	-22.30	35	37.35	12.01	25.34
6	0	16.48	16.48	28.21	-11.73	36	35.52	11.41	24.11
7	0	23.73	23.73	28.36	-4.63	37	33.62	10.82	22.80
8	0	29.22	29.22	28.30	.92	38	31.78	10.22	21.56
9	0	32.67	32.67	28.00	4.67	39	29.88	9.62	20.26
10	0	35.67	35.67	27.66	8.01	40	28.07	9.02	19.05
11	0	40.60	40.60	27.53	13.07	41	26.17	8.42	17.75
12	0	53.80	53.80	28.52	25.28	42	24.27	7.81	16.46
13	0	60.98	60.98	28.67	32.31	43	22.43	7.21	15.22
14	0	63.87	63.87	28.32	35.55	44	20.53	6.61	13.92
15	0	65.40	65.40	27.81	37.59	45	18.70	6.01	12.69
16	0	65.40	65.40	27.11	38.29	46	16.82	5.41	11.41
17	0	65.40	65.40	26.42	38.98	47	14.98	4.82	10.16
18	0	65.40	65.40	25.72	39.68	48	13.08	4.21	8.87
19	0	65.40	65.40	25.03	40.37	49	11.18	3.61	7.57
20	0	65.40	65.40	24.33	41.07	50	9.35	3.00	6.35
21	0	63.52	63.52	23.40	40.12	51	7.45	2.40	5.05
22	0	61.68	61.68	22.49	39.19	52	5.63	1.80	3.83
23	0	59.78	59.78	21.57	38.21	53	3.73	1.20	2.53
24	0	57.95	57.95	20.66	37.29	54	1.90	.61	1.29
25	0	56.05	56.05	19.74	36.31	55	0	0	0
26	0	54.22	54.22	18.82	35.40				
27	0	52.33	52.33	17.91	34.42				
28	0	50.43	50.43	16.98	33.45				
29	0	48.59	48.59	15.94	32.65				
30	0	46.70	46.70	15.02	31.68				

Note: 1. The calculation of costs and revenues is based on Tables A-VII, A-VIII, and A-IX.

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